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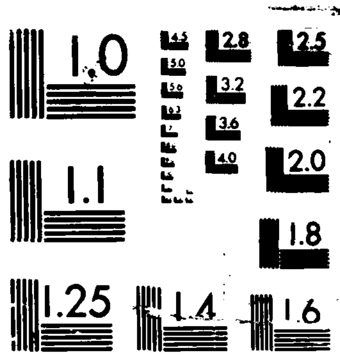

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PERCEIVED EXERTION UNDER CONDITIONS OF SUSTAINED WORK AND SLEEP LOSS

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REPORT NO. 87-9

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SUMMARY

The relationships of perceived exertion to workload, heart rate, fatigue, mood, and sleepiness have been analyzed in two studies involving repeated submaximal treadmill walking while carrying a 22 kg pack. Subjects walked for 17 one-half hour sessions on each of two consecutive days (34 sessions overall). In Study 1 subjects started exercise at 40% of their maximum oxygen consumption. This level was maintained until a subject felt he could no longer complete a half hour exercise session. Subsequently treadmill grade and then speed were reduced as necessary. One group took a 4 hr nap between the first and second continuous work days (CW1 and CW2). The other group was allowed to rest for 4 hrs but not to sleep. Study 2 subjects exercised at 30% of maximum oxygen consumption throughout, with the two CWs separated by a 3 hr nap. One group started the CWs at midnight and the other at noon. In both studies, Ratings of Perceived Exertion (RPE) were recorded half way through each exercise session. Heart rate (HR) and treadmill speed and elevation were averaged over the entire session. Fatigue, mood, symptoms and sleepiness were measured immediately after each session.

There was a significant linear increase in RPE over the sessions during each day and a significant drop in RPE from the last session of CW1 to the first session of CW2. There was no difference between nap or rest conditions or midnight vs noon start times in terms of RPE.

With higher levels of exercise (Study 1, 40% VO2max) RPE was more strongly related to HR and workload measures than during low levels of exercise (Study 2, 30% VO2max). The psychological measures (fatigue, vigor, sleepiness) showed stronger and more persistent relationships with RPE at lower levels of exercise.

PERCEIVED EXERTION UNDER CONDITIONS OF SUSTAINED WORK AND SLEEP LOSS

The Rated Perceived Exertion (RPE) scale was originally developed to reflect Heart Rate changes during stages of maximal exercise testing on a bicycle ergometer (Borg, 1973). This RPE scale has been the central measure in a large number of studies concerning physiological and psychological responses to various types of work and exercise under a wide range of conditions (Pandolf, 1983). The majority of these studies have focused on how the RPE scale relates to physiological responses to exercise (i.e., oxygen consumption, heart rate, lactic acid production, etc.).

Although perceived exertion ratings increase with greater workloads, they have also been found to increase with repeated exposure to exercise with a constant workload (Myles, 1985; Martin and Gaddis, 1981; Martin, 1981; Soule and Goldman, 1973). Whether this increase in RPE with repeated exercise at the same workload is due to the accompanying sleep loss, the cummulative effect of exercise fatigue with repeated work or psychological changes is not well known.

The purposes of this paper are: 1) to document the changes in RPE during both repeated maximal and submaximal exercise over a 40 hr period of intermittent exercise with accompanying sleep loss, and 2) to determine if and when the relationships of RPE and workload level, heart rate, and psychological measures exist.

METHOD

Subjects

Thirty-seven healthy, U.S. Marine Corps volunteer, enlisted personnel gave informed consent and participated in one of two studies. The experimental conditions of the two groups within each of these studies and descriptive characteristics of the twenty-five subjects who completed the studies are in Table 1.

Study 1 involved two groups which were repeatedly exercised (treadmill walking) at 40% of VO2 max while carrying a 22kg pack. Group 1 took a 4hr nap between the two days of continuous work (CW). Only five of the nine exercise subjects starting this group completed at least one half of CW2. Group 2 remained awake for the four hours between the two exercise days, and only five of the ten subjects starting in this group completed one half of CW2.

TABLE 1
STUDY CHARACTERISTICS AND EXERCISE SUBJECTS MEANS AND STANDARD DEVIATIONS FOR AGE, HEIGHT, WEIGHT, MAXIMUM VO_2 AND HEART RATE FOR THE GROUPS IN THE TWO STUDIES

STUDY NO.	GROUP NO.	EXERCISE LEVELS % MAX VO_2	TIME OF CW[1] START	BETWEEN CW NAP LENGTH	N	AGE	HEIGHT cm	WEIGHT kg	MAX VO_2 ml/kg/min	MAX HR BPM
1	1	40%	0800	4 hrs	5	22.2 (1.3)	173.9 (6.6)	77.9 (12.9)	51.5 (7.9)	192 (10.7)
	2	40%	0800	0 hrs[2]	5	21.6 (1.9)	177.6 (2.8)	70.0 (7.6)	52.3 (3.7)	181 (9.7)
2	3	30%	0000	3 hrs	7	21.9 (1.5)	178.0 (5.8)	80.4 (9.2)	51.7 (7.0)	192 (6.9)
	4	30%	1300	3 hrs	8	20.3 (0.9)	171.9 (9.6)	76.6 (11.6)	48.5 (3.3)	199 (10.4)

STUDY 1 (40% VO_2 START)
STUDY 2 (30% VO_2 TIME SHIFTED)
[1]CW = Continuous Workday
[2]These subjects remained awake for the 4 hrs between the two Continuous Workdays.

Study 2 used a constant 30% of VO2 max exercise level over the two days with Group 3 starting exercise at midnight and Group 4 starting at 1300. Both groups started with nine subjects, but because of subjects withdrawing and equipment and data collection problems, only seven remained in Group 3 and eight in Group 4.

Schedule

Subjects were tested in pairs. One subject in each pair was randomly selected as a control (non-exercising) while the other exercised during the third and fourth days. Studies lasted for five days.

On Day 1 a maximal stress test was done, medical and exercise histories were taken, and the subjects were trained in taking the psychological questionaires and the various tasks they would be performing during testing (see Ryman et al, 1984, for details). Day 2 involved further practice with the questionaires and tasks with no exercise. This served as a baseline training day.

Days 3 and 4 were called the first and second continuous work day (CW1, CW2). Each day involved 17 1-hr sessions. During the first half-hour of each session both subjects performed a vigilance task responding to specific letters and numbers flashed at random intervals on a screen. The control subject did this while seated at a computer terminal. The other subject performed the task while undergoing submaximal treadmill exercise. During the second half-hour the various tasks and psychological tests were performed. There was a 30 minute meal break between sessions 4 and 5 and 45 minute break after session 8.

In Study 1, Group 1 started at 0800 on Day 3 (CW1) and slept 4 hours between the two CWs. Group 2 started at the same time but remained awake throughout the study (4 hr rest period between CW1 and CW2). Both Group 1 and 2 Ss slept from 2300-0700 on the two days before the start of CW. In Study 2, Group 3 started CW1 at midnight and group 4 started at 1300, with both groups taking a 3 hr nap between the CWs. Group 3 slept from 1900 to 0300 the night of Day 1 and 1500 to 2300 Day 2, and Group 4 slept from 0100 to 0900 the night of Day 1 and 0300 to 1100 Day 2 in preparation for these work schedules. Following CW2 there was an 8 hour recovery sleep after which maximal treadmill testing was done in Study 2.

Maximal Exercise Testing

All exercise was performed on a motor-driven treadmill (Quinton Model 18-60). Resting EKG, heart rate, and blood pressure were checked prior to every maximal exercise test.

Study 1

In Study 1, one maximal exercise test (MET) was given on Day 1 between 1100 and 1200. Subjects wore running shoes and shorts. The test started with a three minute warm-up, walking at 4.8 kph (3 mph). This was followed by two minute stages of running, starting at 8.9 kph (5.5 mph) with a 0.8 kph (0.5 mph) speed increase at each stage until the ventilatory equivalent consumption of oxygen (VE/VO2) reached a steady state (usually at 12.8-16.1 kph, 8-10 mph). After this the treadmill grade was increased 2% every minute until VO2 did not increase or the subject reached exhaustion. Expired volume and gases were measured along with the treadmill speed and grade, and VO2 ml/kg/min was computed with an on-line computer (DEC MINC-11).

Study 2

The time shifted study included three maximal exercise tests, as follows:

1. Day 1 - baseline test, given between the hours of 1000 and 1200.
2. Day 4 - post-exercise/sleep deprivation test given immediately after completion of CW2 at about 2100 (midnight group) or 0800 (noon group).
3. Day 5 - recovery test given after the 8 hr recovery sleep which followed CW2, around 0800 (midnight group) or 1900 (noon group).

These stress tests were performed with the subjects wearing camouflage fatigues and boots and carrying packs (total weight of packs and gear was 22kg). The test started with a two minute rest period with the subject standing on the treadmill, then the subject walked on the treadmill at 4.8 kph (3 mph) with zero grade for two minutes. The grade was raised 2% every two minutes thereafter until exhaustion. Expired ventilatory volume and gases (percent O_2 and CO_2) were monitored along with heart rate, EKG, core temperature, and treadmill speed and grade via on-line computer (see Submaximal Exercise section below and Yeager et al., 1987 for complete details).

The RPE scale was administered one minute into each MET stage. The onset of breathing difficulty, leg cramps or other symptoms were indicated by prearranged hand signals. After the test was completed the subject was monitored until heart rate was down to 120-130 beats per min. Reasons for stopping the tests were classified as leg cramps or leg fatigue, breathing difficulty, complete exhaustion, and/or others. Multiple reasons for stopping a test were allowed.

Submaximal Exercise Sessions

Five minute averages of oxygen consumption were monitored, and the speed was adjusted to maintain oxygen consumption at the appropriate level. Data collected during the 1/2 hour testing sessions included:

1. Average speed and elevation of treadmill - The analog voltage from the speed and elevation control dials was sent to an A/D converter in a DEC MINC-11 minicomputer where the minute averages were calculated and stored.
2. Heart rate in beats per minute - For Groups 1, 2, and 3, heart rate was monitored using the standard CM5 placement of long term electrode

leads. Output of these leads was processed by a pulse shaper then sent to a Schmitt trigger on the MINC-11 minicomputer. The minute counts were stored for each exercise session or stress test. For Group 4, a Transkinetics telemetry system (TEM 4000) was used to transmit the EKG to a receiver-monitor. The output from the monitor was processed by the same pulse shaper and Schmitt trigger used with the other groups.

3. The RPE scale - The Borg scale was presented to the subject at the half way point (15 mins into the 1/2 hr) of each exercise session. The subject was asked to "select the number which best describes the workload you are now experiencing." The scale numbers range from 6 to 20, with 7 being "very, very light" and 19 being "very, very hard".

Study 1

Subjects were started at a combination of a speed greater than 6.4 kph (4 mph) and a grade between 1 and 6%, sufficient to produce an oxygen consumption of 40% VO2max. Most subjects could not maintain the 40% VO2max workload past the first eight sessions. The grade and speed were then adjusted downward to a rate which the subject could maintain for an entire 1/2 hour treadmill walk session (see Figure 1).

Study 2

Subjects were started at a speed of less than 4.8 kph (3 mph) and a grade of 1 to 3%, sufficient to produce an oxygen consumption of 30% VO2max (see Figure 1). One subject had to walk at a grade of -1 to 0% because of a previous knee injury. All subjects were able to maintain this workload through CW1 and CW2 (see Figure 1). Group 3 started CW1 at 1300 on Day 3. Group 4 started CW1 at 2400 (between Day 2 and Day 3).

Psychological Measures

A computer-administered series of psychological questionnaires were given immediately after each 1/2 hr exercise session (Ryman et al. 1984). These included:

1) the Profile of Mood States Vigor and Fatigue scales (POMS) (McNair et al. 1971),
2) the School of Aerospace Medicine (SAM) Fatigue scale (Pearson and Byars, 1956),

3) the total symptoms from the Kogi Symptom checklist (Kogi et al. 1970),

4) the Naval Health Research Mood Questionnaire (NHRC MQ) Negative and Positive scales (Moses et al. 1974), and

5) the Stanford Sleepiness Scale (SSS) (Hoddes et al. 1973).

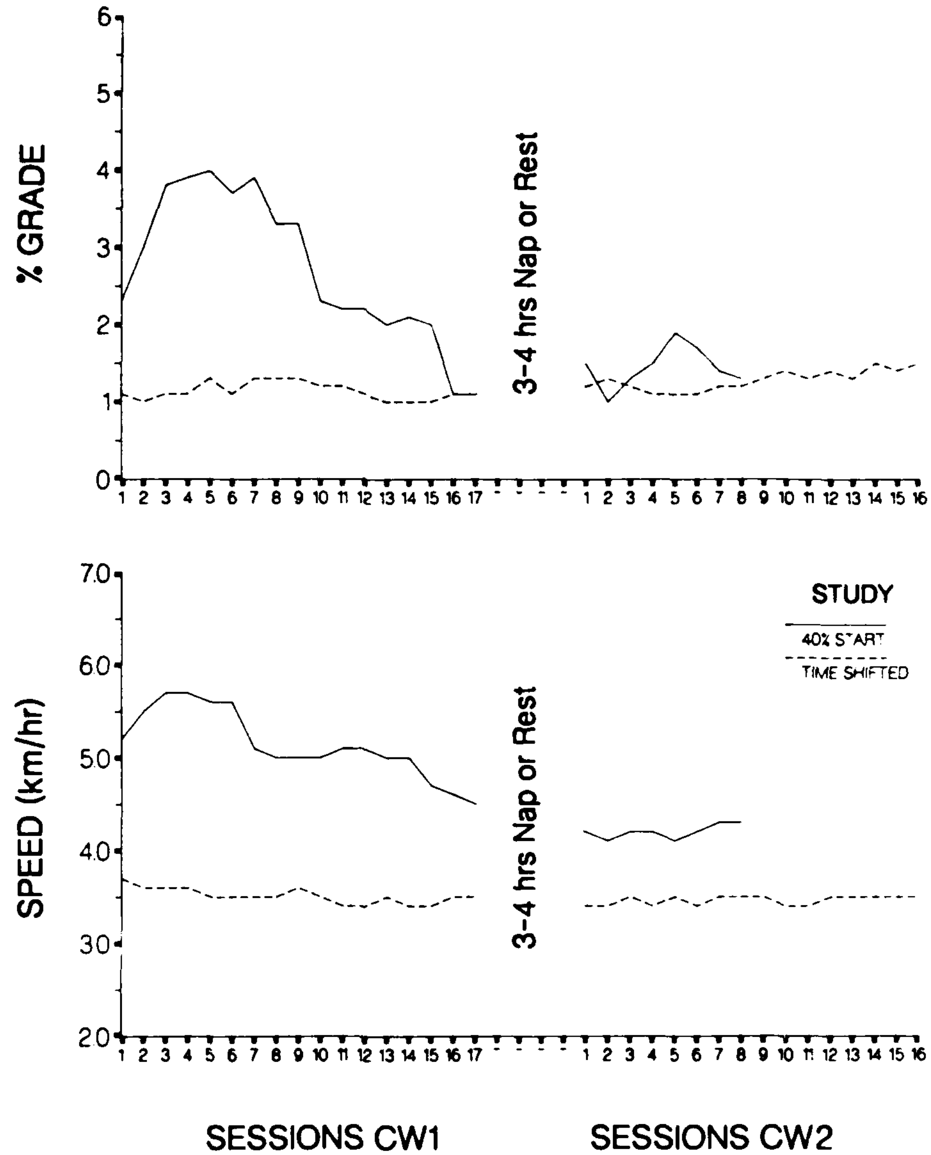

Figure 1. Treadmill Speed Km/hr (Lower graph) and Elevation % Grade (Upper graph) Session Means for Study 1 (40% V02 Start) and Study 2 (Time Shifted) over Two Continuous Workdays.

Statistical Analysis

Multivariate analyses of variance (SPSSX MANOVA; Norusis, 1985) were done to determine which experimental conditions had significant effects on RPE. RPE from the submaximal testing in Study 1 and Study 2 served as the dependent variable. The repeated measures were time periods (averages of Day 1 sessions 1-4, 5-8, 9-12, and 13-17, and Day 2 sessions 1-4 and 5-8), with groups of nap vs no nap in Study 1. Repeated measures were time periods (averages of sessions 1-4, 5-8, 9-12, and 13-17 on both days) and days, with groups of noon vs midnight start for Study 2 .

Analyses of variance (ANOVA) were done on RPEs from each maximum stress test in Study 2 between the four groups (breathing difficulty, leg cramps/leg fatigue, exhaustion, and others) for reasons for quitting. Student's t-tests between the single reason for stopping vs multiple reasons for stopping for the three maximal tests were also done. Many subjects had different reasons for stopping each maximal test; therefore, one MANOVA could not be performed.

T-tests of RPE immediately pre- and post-CW break conditions were done to determine the recovery effects between the groups in both studies. Correlations of the RPE means found to be significant in the MANOVA results and the average speed, elevation gains, and heart rate at those periods for both studies were computed to determine the relationship of workload and heart rate with RPE. RPE and heart rate were correlated at the same time periods to determine if, when, and to what degree these measures were related. Also, correlations of the measures and RPE averages were done to estimate the contribution of these variables to RPE.

RESULTS

MANOVA Results

The MANOVAs showed no differences in RPE between either Group 1 and Group 2 (nap vs no nap, $F(1,9) = 2.94$, $p = .125$), or Group 3 and Group 4 (noon vs midnight start, $F(1,14) = .27$, $p = .61$). Both studies showed significant differences between the sessions ($F(5,7) = 14.67$, $p < .007$ for Study 1, $F(3,12) = 22.00$, $p < .001$ for Study 2), with a linear trend of increasing RPE from first to last session ($F(1,3) = 12.62$, $p = .04$ for Study 1, $F(1,3) = 20.74$, $p = .02$ for Study 2) (see Table 2A and 2B). There were significantly higher RPEs during CW2 as compared to CW1 ($F(1,14) = 5.08$, $p = .04$). A steady increase in RPE over both days can be seen in Figure 2.

Figure 2 also shows the decreasing HR in Study 1, whereas HR was more stable in Study 2.

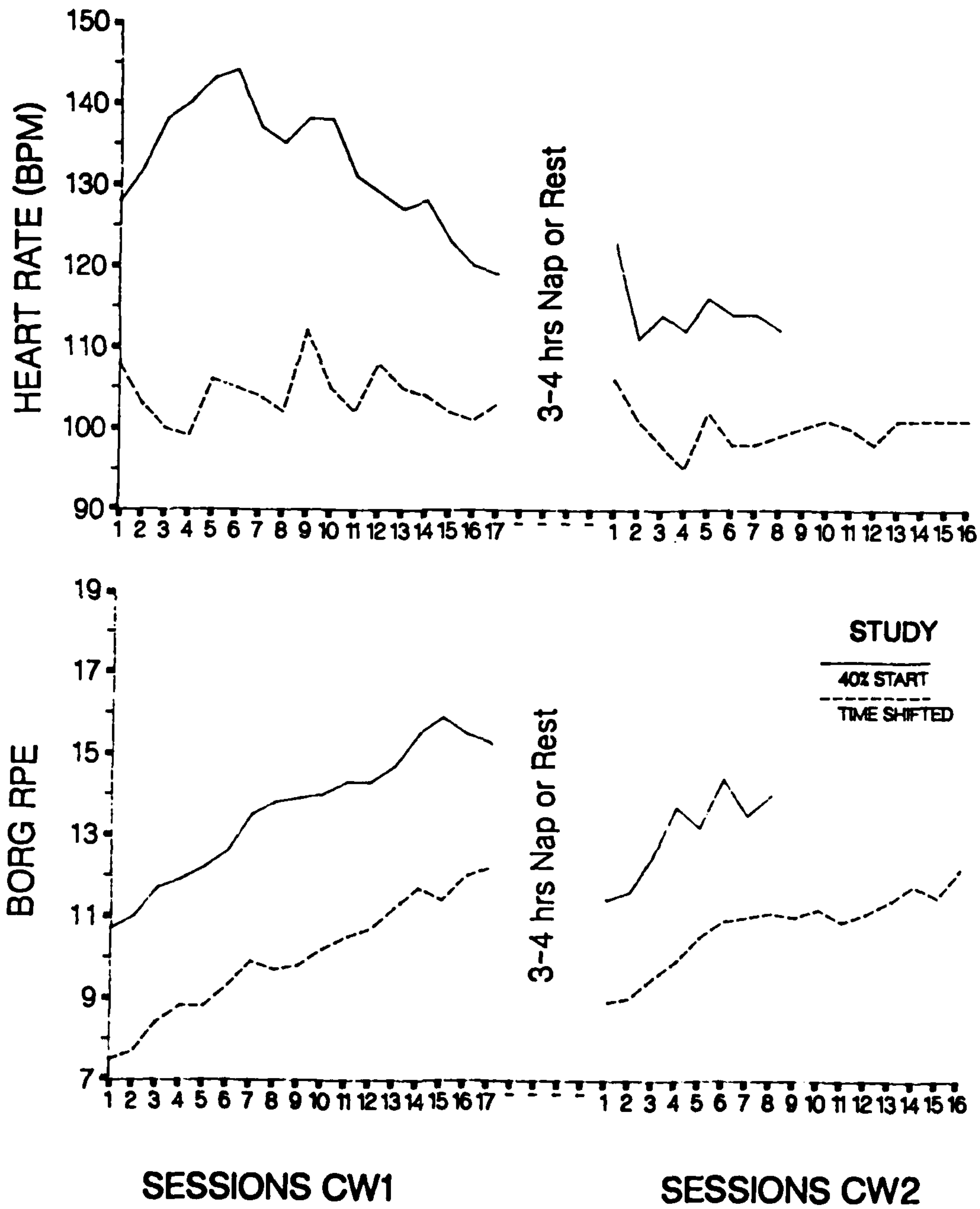

Figure 2. Borg's Rated Perceived Exertion (Lower graph) and Heart Rate in Beats per minute (Upper graph) Session Means for Study 1 (40% VO2) and Study 2 (Time Shifted) over Two Continuous Workdays.

TABLES 2A, 2B
MEANS AND STANDARD DEVIATIONS FOR RATED PERCEIVED EXERTIONS (RPE) FOR STUDY 1 AND STUDY 2

A. STUDY 1 RPE SESSIONS MEANS (40% VO_2 SUBMAXIMAL START EXERCISE GROUPS)

GROUP CONDITION	DAY CW1				CW2		
SESSIONS	1-4	5-8	9-12	13-17	1-4	5-8	N
40% START* 4 hr NAP	12.2 (1.2)	13.8 (1.5)	14.7 (2.0)	16.0 (2.4)	13.2 (1.7)	14.6 (1.9)	5
40% START* NO NAP	10.9 (2.4)	12.4 (1.6)	13.4 (0.4)	15.1 (1.3)	11.5 (1.5)	13.5 (1.7)	5

$_{SESSIONS}$ = 14.67, df = 5, 8 p = .007

*Workload (treadmill speed and grade) initially set to produce 40% of Maximum VO_2, both groups started walking at 0800 on CW1 and CW2.

B. STUDY 2 RPE SESSION MEANS (TIME SHIFTED 30% SUBMAX EXERCISE GROUPS)

GROUP CONDITION	DAY CW1				CW2				
SESSIONS	1-4	5-8	9-12	13-17	1-4	5-8	9-12	13-17	N
MIDNIGHT 30%-3 hr NAP	8.5 (2.3)	9.2 (2.6)	9.4 (2.1)	10.5 (2.8)	9.9 (4.0)	11.1 (4.3)	10.3 (2.9)	11.0 (3.4)	7
NOON (1300) 30%-3 hr NAP	7.8 (1.3)	9.8 (2.7)	10.9 (2.9)	12.5 (2.9)	9.7 (2.2)	10.8 (2.1)	11.6 (2.6)	12.1 (3.2)	8

$F_{DAYS} = 5.08$, df = 1, 14 $p = .04$; $F_{SESSIONS} = 22.00$, df = 3, 12 $p < .001$

ANOVA Results

There were no differences in RPE among the three maximal treadmill tests or between the midnight and noon start groups in Study 2. There were no differences in RPE or maximum V02 among the reason-for-stopping groups for any of these tests. This shows that the subjective reasons for stopping these maximum stress tests do not result in either attained max V02 or max RPE differences. RPE showed linear increases over the stages of the tests. RPE correlated with elevation increases (r=.82 to .89), V02 (r=.53 to .83), and heart rate (r = .64 to .75) over all stages during each of the three maximum tests. This indicated that the changes in workload level are significant in RPE changes during maximal exercise testing even after two days of sleep loss with repeated submaximal exposure.

T-Test Results

RPE dropped significantly between the session immediately prior to the break (the last session of the CW1) to the session post-break (the first session of the CW2) ($t = 5.81$, $p < .001$, $df = 9$ in Study 1; $t = 6.27$, $p < .001$, $df = 14$ in Study 2). The magnitudes of these changes (pre minus post) were similar in Groups 1 and 2 (nap and no nap) and in Groups 3 and 4 (noon vs midnight start). This indicates that there is a recovery in RPE with a 3-4 hour break, but it is not due to nap-rest or time of day differences.

Correlations

Since there were no significant differences between the RPEs of the 4 hour nap and the 4 hour rest groups in Study 1, they were combined as one group for the computation of the correlations between RPE and workload, heart rate, and psychological measures. Similarly, in Study 2 the groups did not

TABLE 3A. MEANS AND STANDARD DEVIATIONS AT SIX SUBMAXIMAL EXERCISE PERIODS FOR HEART RATE, SPEED, AND ELEVATION GAINED IN STUDY 1

DAYS	CW1				CW2	
SESSIONS	1-4	5-8	9-12	13-17	1-4	5-8
HEART RATE (BPM)	138 (18)	141 (17)	133 (17)	123 (18)	114 (18)	112 (15)
SPEED (km/hr)	5.7 (0.7)	5.4 (0.6)	5.1 (0.8)	4.8 (1.0)	4.2 (1.0)	4.1 (0.9)
ELEV GAIN (m/hr)	99.5 (31.4)	94.3 (52.6)	57.0 (48.8)	37.1 (53.4)	30.3 (46.7)	31.1 (44.2)

TABLE 3B. CORRELATIONS BETWEEN BORG RPE AND HEART RATE, SPEED AND ELEVATION GAINED AT SIX SUBMAXIMAL EXERCISE PERIODS IN STUDY 1

DAYS	CW1								CW2			
SESSIONS	1-4		5-8		9-12		13-17		1-4		5-8	
	r_p	r_s	r_p	r_s	r_p	r_s	r_p	r_s	r_p	r_s	r_p	r_s
HR (BPM)	.86	.77	.57	.62	.68	.44	.52	.48	.13	.09	.09	−.01
p	<.001	.005	.04	.03	.02	--	--	--	--	--	--	--
SPEED	.31	.39	−.19	−.15	−.36	−.48	−.51	−.31	−.28	−.10	.11	−.03
p	--	--	--	--	--	--	--	--	--	--	--	--
ELEV GAIN	.57	.66	−.28	−.12	.60	.45	.58	.60	.20	.19	.05	−.04
p	.04	.02	--	--	.03	--	.04	.03	--	--	--	--

r_p = *Pearson Product Moment Correlation Coefficients*

r_s = Spearman Rank Order Correlation Coefficients

-- = not significant ($p > .05$, $df = 9$, one-tailed) differ in RPE, so they were combined for these computations. RPE varied greatly over the different time periods in both studies, so the correlations were computed separately at each period.

Speed, Elevation Gain and Heart Rate

In Study 1, with the higher initial workload, there were significant correlations between RPE and mean elevation gain and mean heart rate but not

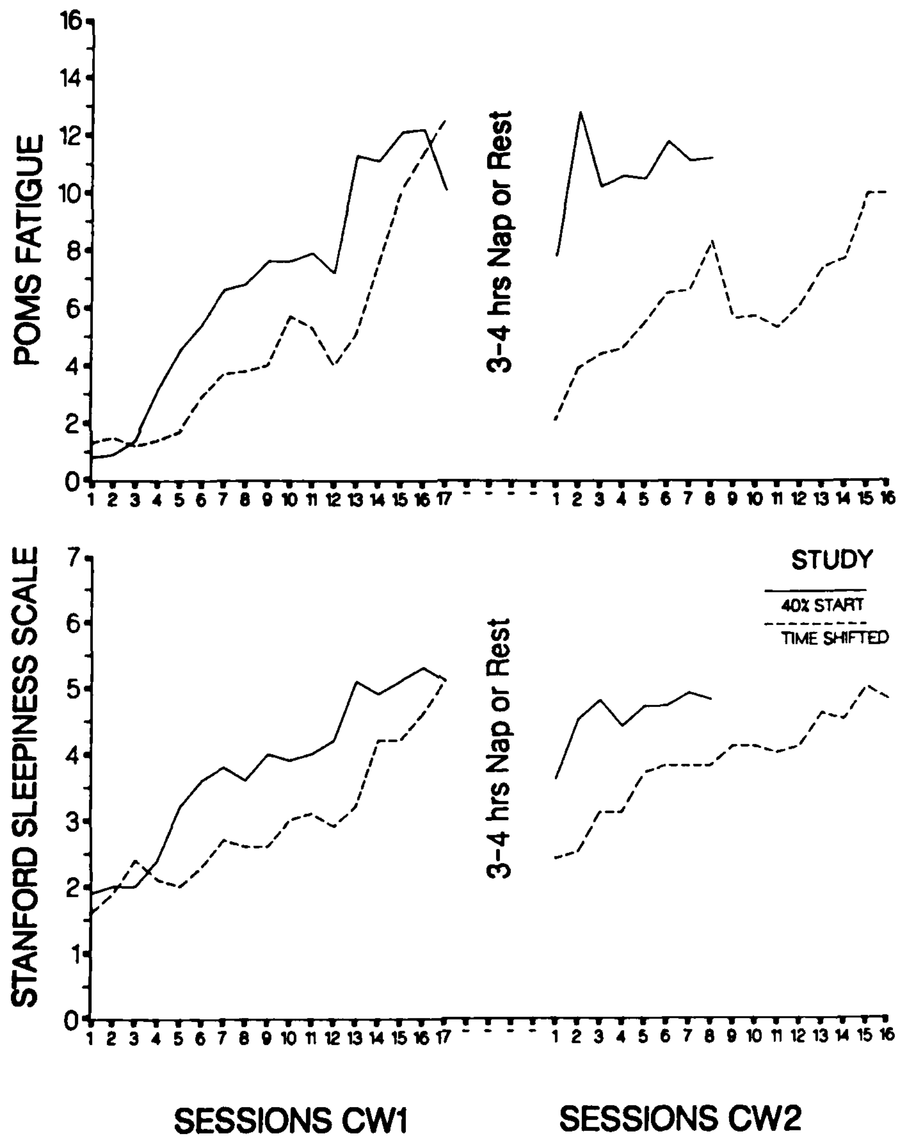

Figure 3. Stanford Sleepiness Scale (Lower graph) and Profile of Mood States Fatigue Scale (Upper graph) Session Means for Study 1 (40% VO2 Start) and Study 2 (Time Shifted) over Two Continuous Workdays.

treadmill speed during most time periods of CW1 (see Table 3). None of these correlations were significant during CW2. In Study 2, with a constant 30% workload, there were no significant correlations between RPE and any of these measures on either day.

Psychological Measures

In Study 1 there were no significant correlations between RPE means and any of the psychological measures except during the third time period (sessions 9 - 12, see Table 4A) of CW1. During this time period the mean RPE had a negative correlation with the POMS Vigor scale mean and significant

TABLE 4A & 4B
SIGNIFICANT CORRELATIONS BETWEEN BORG RPE AND FATIGUE, SYMPTOM, MOOD AND SLEEPINESS (SSS) SCALES
STUDY 1 AND STUDY 2 DURING CW1 ONLY[1]

A. STUDY 1 40% VO_2 START (n = 10)[2]

	POMS[a]				Kogi		SAM		NHRC MQ[b]			
	VIGOR		FATIGUE		SYMPTOMS		FATIGUE		NEGATIVE		SSS[c]	
SESSIONS	r_p	r_s	r_p	r_s	r_p	r_s	r_p	r_s	r_p	r_s	r_p	r_s
9-12	−.65	−.59	.57	.59	.46	.31	.50	.54	.58	.57	.73	.67
p	.02	.03	.04	.03	--	--	--	--	.04	.05	.01	.02

B. STUDY 2 TIME SHIFTED (n =15)[2]

	POMS[a]				Kogi		SAM		NHRC MQ[b]			
	VIGOR		FATIGUE		SYMPTOMS		FATIGUE		NEGATIVE		SSS[c]	
SESSIONS	r_p	r_s	r_p	r_s	r_p	r_s	r_p	r_s	r_p	r_s	r_p	r_s
5-8	−.52	−.59	.64	.66	−.18	−.19	.40	.45	.66	.50	.62	.77
p	.03	.01	.005	.004	--	--	--	--	.004	.04	.005	.002
9-12	−.60	−.65	.77	.60	.61	.73	.77	.80	.85	.69	.78	.80
p	.01	.001	<.001	.01	.01	<.001	<.001	<.001	<.001	.003	<.001	<.001
13-17	−.53	−.47	.85	.76	.55	.39	.58	.70	.82	.65	.54	.47
p	.02	.05	<.001	<.001	.03	--	.01	.002	<.001	.001	.02	.04

[1]No significant correlations were found at any time period in CW2 for either study. There were also no significant correlations between the NHRC MQ Positive Scale and RPE at any time periods on either day.

[2]Since there were no significant differences in RPE between either the 40% start groups (4 hr Nap and 4 hr Awake), and either 'Time Shifted' groups, these groups were analysed by study in computing these correlations.

r_p = Pearson Product Moment Correlation Coefficients

r_s = Spearman Rank Order Correlation Coefficients

p = one-tailed significance levels, -- = not significant ($p > .05$)

[a]Profile of Mood States

[b]Naval Health Research Center Mood Questionnaire

[c]Stanford Sleepiness Scale

positive correlations with the POMS Fatigue, the NHRC MQ Negative, and the Stanford Sleepiness Scale (SSS) means. The steady increases in sleepiness and fatigue each day for both studies can be seen in Figure 3.

In Study 2 (see Table 4B), the same significant relationships existed during the same third time period of CW1. Additionally, there were significant positive correlations of RPE with Kogi Symptoms and SAM Fatigue. POMS Vigor, POMS Fatigue, and SSS showed the same relationships with RPE during the second time period (sessions 5-8). RPE was still correlated negatively with POMS Vigor and positively with POMS Fatigue, SAM Fatigue, and NHRC Negative during the fourth time period OF CW1 (sessions 13-17).

DISCUSSION

Most of the previous studies have found a linear increase in RPE with prolonged, repeated exercise (Myles, 1985, Martin, 1981; Soule and Goldman, 1973). Both of the present studies give similar results. Perceived exertion showed a linear increase in each day with repeated submaximal exercise even though in Study 1 the workload was decreasing.

Soule and Goldman (1973), using a self-paced treadmill exercise protocol with subjects walking 6 1-hr periods over 31 hrs while carrying 15kg or 30kg, found increasing RPE levels similar to Study 2. Myles (1985) used a workload of 28% of VO2max (similar to our Study 2) in his first study, with subjects walking 50 minutes every 3 hrs over 60 hrs with no pack. He found a linear increase in RPE values very close to what we found in Study 2 (8.7 at baseline and 11.2 after 60 hrs). Martin and Gaddis (1981) tested subjects at 25%, 50% and 75% of VO2max over three days (control day, after 30 hr sleep loss, and after unlimited recovery sleep). They found increased RPE with sleep loss for only the 50% and 75% levels. Martin (1981) walked subjects at 80% VO2max on a treadmill (5.6 kph with 10-21% grade) and he found RPE changes and values before and after 36 hrs sleep deprivation similar to our Study 1.

The relationships of the RPE scale with treadmill, elevation gain, and heart rate were significant during most of CW1 in Study 1 but not during either day in Study 2. In Soule and Goldman's study (1973) which had similar speed as that used in Study 2, the correlations between heart rate and perceived exertion were low and not significant. They attributed these findings to the narrow range of heart rate seen in their subjects. In Study 1 (40%

VO2max), the protocol produced a broader range of HR. Thus our findings support Soule and Goldman's explanation. Kinsman and Weiser (1976) used the same explanation for the decreased relationship found by Gamberale (1972) between the RPE scale and heart rates during weight lifting and wheel-barrow work as compared to bicycle ergometer testing. A narrower range of heart rates was seen during the first two activities. In the third study of Myles (1985) subjects performed a series of 15 minute treadmill runs at 70% of VO2max. They were allowed 5 minute rest periods between the runs and continued until they had completed a total of 2 hours of running or until exhaustion. The same SAM Fatigue scale was used as in the present study. The SAM Fatigue and RPE increased in each successive 15 minute bout of walking in that study, suggesting a correlation (although correlation coefficients were not calculated in that study).

Perceived exertion correlated at higher significance levels over more time periods during CW1 with the subjective ratings of fatigue, sleepiness, and mood in Study 2 than in Study 1. Apparently, at lower levels of exercise, perceived exertion correlates poorly with actual workload and heart rate; however, it does reflect the subject's psychological factors. Significant correlations were present in both studies during the third period CW1 (sessions 9-12) and appeared to be highest for most measures in this time period in Study 2. Possibly the significant correlations at this time period indicate a "warm-up" or "second wind" effect that occured in some subjects after the first 8 sessions. This effect may result in these subjects having lower RPE, mood and fatigue changes while other subjects continued to increase in these measures resulting in these significant correlations. Another possible explanation is that denial of RPE and psychological fatigue and willingness to admit both of these factors occurs after inital exposure of repeated exercise. The lack of any correlations in either study on CW2 suggests that sleep deprivation and/or continued exercise decreases any relationships between RPE and both physiological and psychological parameters.

In Study 1 the nap and rest conditions were found to have a similar decrease in perceived exertion from the end of CW1 to first session CW2, showing no greater recovery in RPE with a nap of this duration (4 hrs) than seen with rest alone.

In Study 2, the noon start vs midnight start conditions produced no changes in the pattern of perceived exertion. If workload elicits a higher sensation of exertion at the low point of the circadian cycle, one might expect to see an overlay of the circadian effect generating different patterns in the noon vs the midnight groups. Perhaps the preparatory sleep time adjustments the two groups experienced on Days 1 and 2 adjusted their circadian cycles sufficiently to obscure such effects.

In summary, the initial increases found in RPE the first day with repeated exercise appear to reflect the workload and physiological conditions only at higher workloads. At lower levels of workload, RPE reflects psychological fatigue and sleep loss perceptions after some initial continued, repeated exercise. The RPE after continued, repeated exercise of more than one day does not seem to reflect workload, physiological responses, or psychological perceptions of fatigue or sleep loss.

REFERENCES

Borg, G. 1973, Perceived exertion: A note on "history" and methods. Medicine and Science in Sports, 5, 90-93.

Gamberale, F. 1972, Perceived exertion, heart rate, oxygen uptake and blood lactate in different work operations. Ergonomics, 15, 545-553.

Hoddes, E., Zarcone, Smythe, H., Phillips, R., and Dement, W.C. 1973, Quantification of sleepiness: A new approach. Psychophysiology, 10, 431-436.

Kinsman, R.A. and Weiser, P.C. 1976, Subjective symptomology during work and fatigue. In Simonson, E. and Weiser, P.C. (Eds.), Psychological Aspects and Physiological Correlates of Work and Fatigue, (Springfield, IL., Chas. Thomas, Publishers).

Kogi, K., Saito, Y., and Mitsuhashi, T. 1970, Validity of three components of subjective fatigue feelings. Journal of Science and Labour, 46, 251-270.

Martin, B.J. 1981, Effect of sleep deprivation on tolerance of prolonged exercise. European Journal of Applied Physiology, 47, 345-354.

Martin, B.J. and Gaddis, G.M. 1981, Exercise after sleep deprivation, Medicine and Science in Sports and Exercise, 13, 220-223.

McNair, D.M., Lorr, M., and Droppleman, L.F. 1971, Manual of Profile of Mood Scale. (San Diego, CA: Educational and Industrial Testing Service).

Moses, J.M., Lubin, A., Naitoh, P., and Johnson, L.C. 1974, Subjective evaluation of the effects of sleep loss. The NHRC mood scales (Tech Rep No. 74-25, San Diego, CA: Naval Health Research Center).

Myles, W.S. 1985, Sleep deprivation, physical fatigue and the perception of exercise. Medicine and Science in Sports and Exercise, 17, 580-584.

Norusis, M.J. (Ed.) 1985, Advanced Statistics Guide SPSSX, (New,York: McGraw-Hill).

Pandolf, V.B. 1983, Advances in the study and application of perceived exertion. In Terjung, R.L. (Ed.), Exercise and Sport Sciences Reviews. (Philadelphia. PA.: Franklin Institute Press).

Pearson, R.G., and Byars, G.E. 1956, The development and validation of checklist for measuring subjective fatigue. (Tech Rep No. 56-116 San Antonio, TX: U.S. Air Force School of Aerospace Medicine).

Ryman, D.H., Naitoh, P., and Englund, C.E. 1984, Minicomputer-administered tasks in the study of sustained work on human performance, Behavior Research Methods, Instruments & Computers, 16, 256-261.

Soule, R.G. and Goldman, R.F. 1973, Pacing of intermittent work during 31 hours. Medicine and Science in Sports, 5, 128-131.

Yeager, J., Crisman R., and Sucec, A. 1987, The effect of sleep deprivation and moderate intermittent exercise on maximal aeorbic capacity, (NHRC Tech Report 86-36, San Diego, Ca.: Naval Health Research Center).

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The relationships of perceived exertion (RPE) to workload, heart rate, and psychological measures during repeated treadmill walking while carrying 22kg have been analyzed in 2 studies. Exercising subjects alternated 30 min walks with 30 min of tasks for 16 one hr sessions on each of 2 consecutive days. Study 1 used an initial treadmill grade and speed producing 40% maximum oxygen consumption (VO2 max). This level was maintained until a subject could no longer complete a 30 min exercise session. Subsequently treadmill grade and then speed were reduced to a maintainable rate. Subjects got a 4 hr nap (Group 1) or rest (Group 2) between days. Study 2 used 30% VO2 max throughout and a [illegible] hr nap between days; one group started at midnight, the other at noon.

Both studies showed a linear increase in RPE during each day ($p < .001$) [illegible] from the end of Day 1 to the start of Day 2 ($p < .001$). Napping rather than just resting, or starting at midnight rather than at noon did not change RPE. RPE was higher Day 2 than Day 1 in Study 2 ($p < .05$). RPE increased through the stages of the maximal treadmill tests but did not vary among the [illegible] tests in Study 2.

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RPE was significantly correlated with heart rate, speed, and elevation gained (r and/o p) during most of Day 1 in Study 1 but not in Study 2. Psychological measures showed correlations with RPE only during the third 4 hr period of Day 1 in Study 1 for fatigue, vigor and sleepiness while these relationships persisted through most of Day 1 in Study 2

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